

Synthesis, Optical and Thermal studies on novel nonlinear optical L–Histidine Sodium Thiosulphate crystal by solution growth technique

M. Radha Ramanan¹, R. Radhakrishnan², S. Krishnan³, V. Chithambaram^{4*}

¹ Department of Physics, Arasu Engineering College, Kumbakonam

² PG & Research, Department of Physics, Jamal Mohamed College, Tiruchirappalli

³ Department of Physics, B.S Abdur Rahman University, Vandaloor, Chennai

^{4*} Research Centre Physics, Dhanalakshmi College of engineering, Tambaram, Chennai,

*Corresponding author's email: chithambaramv@gmail.com

Abstract— A semi organic non-linear optical single crystal of L–Histidine Sodium Thiosulphate has been grown from aqueous solution by slow evaporation technique. The lattice parameters of the grown crystals were identified using single crystal X-ray analysis. The functional groups present in the crystal were identified using FTIR analysis. Optical absorption studies have confirmed that the grown crystal possesses less absorption in the entire visible region and UV cut-off is found to be at 230 nm. Thermal stability of the grown crystal was identified from TG-DTA analysis. The mechanical properties of the grown crystals have been studied using Vickers micro hardness tester for different loads. The presence of second harmonic generation (SHG) for the grown crystal was confirmed by Kurtz powder technique.

Keywords: FTIR, SHG, NLO, LHSTSP

I. INTRODUCTION

In recent years, most of the NLO Researchers are working with the idea of combining such high optical non linearity of organic compound with the favorable mechanical and thermal properties of inorganic materials [1]. Today, nonlinear optical (NLO) materials have been studied extensively for their possible applications in various technologies such as telecommunication, optical computing, optical data storage and optical information processing [2 – 9]. NLO crystals with high conversion efficiencies for second harmonic generation (SHG) and transparent in visible, ultraviolet ranges are required for various devices in the field of optoelectronics and photonics [10-12]. To be useful in this technology, the materials should possess large second order optical nonlinearities, short transparency cutoff wavelength and good thermal stability. Organic materials possess good optical non-linearity compared with inorganic crystals but they are thermally unstable and exhibits low laser damage threshold [13]. Semi organic crystals have large damage threshold, wide transparency range, less deliquescence, excellent nonlinear optical coefficient, low angular sensitivity and exceptional mechanical properties [14, 15]. In this connection, amino acids are interesting materials for NLO applications as

they contain a proton donating carboxyl group (COO⁻) and a proton accepting amino (NH₃⁺) in them except for glycine [16]. Amino of L-Histidine has been exploited for the formation of salts with inorganic acids. In this present work, single crystals of L- Histidine Sodium Thiosulphate, a novel nonlinear optical material, have been grown by slow evaporation technique.

2. EXPERIMENTAL

2.1 Materials and Crystal Growth

The materials were synthesized by taking L-Histidine (AR grade) and sodium thiosulphate (AR grade) in a 1:1 stoichiometric ratio. The required amount of starting materials for the synthesis of L- Histidine Sodium Thiosulphate (LHSTS) crystal was calculated according to the following reaction:



The calculated amount of Sodium thiosulphate was first dissolved in deionized water. L-Histidine was then added to the solution. The solution was agitated with a magnetic stirring device for 12h continuously and filtered after complete dissolution of the starting materials. The prepared solution was allowed to dry at room temperature and the crystals were obtained by slow evaporation technique. Optically good quality needle shape single crystals having dimensions 15x2x2 mm³ were grown within the period of 20-25 days. The photograph of as grown crystal of LHSTSP is shown in the fig. 1.

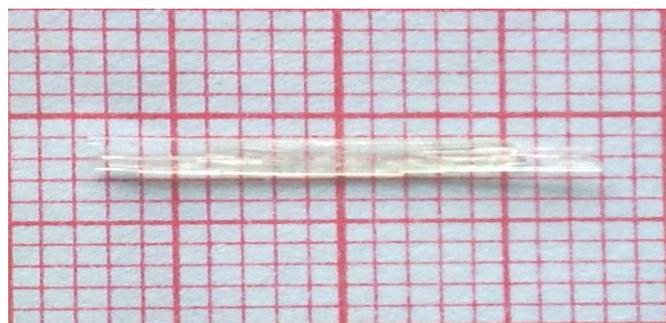


Fig.1.As grown LHSTSP crystals

3. RESULTS AND DISCUSSION

3.1. Single crystal X-ray diffraction

The grown crystals were subjected to single crystal X-Ray diffraction analysis using ENRAF NONIUS CAD4 X-ray diffractometer to determine the cell parameters. The grown crystal belongs to monoclinic system having space group P and the lattice parameters are $a=5.341 \text{ \AA}$, $b=7.301 \text{ \AA}$, $c = 18.739 \text{ \AA}$. And $\beta=90.3^\circ$.

3.2. FTIR analysis

The FTIR spectrum was recorded using Bruker IFS 66V spectrophotometer by KBr pellet technique in the region $4000 - 400 \text{ cm}^{-1}$ and is shown in Fig 2

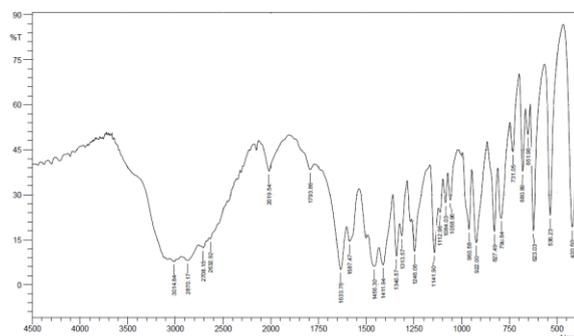


Fig.2.FTIR Spectrum of LHSTS crystals

Vibrational spectroscopy is useful in the identification of functional groups. Molecular vibrational information can be obtained from the absorption or emission of infrared radiation and also from the inelastic scattering of light. Infrared radiation, when incident upon matter is capable of giving indirect but very valuable information on molecular structure. The frequency assignments are presented in Table 1.

FTIR frequency(cm-1)	Band Assignment
3016	N - H stretch
1793	C=O stretching vibrations
2632(vs)	NH ₃ ⁺ symmetric stretching
1633 (vs)	C=N stretching
1587 (ms)	imidazole ring in Histidine
1456 (vs)	N=C=N stretching
1141	COO- Stretching
836	NH ₂ Wagging
425	C - N - C bending

Table 1. FTIR Functional groups

3.3. Optical absorption studies:

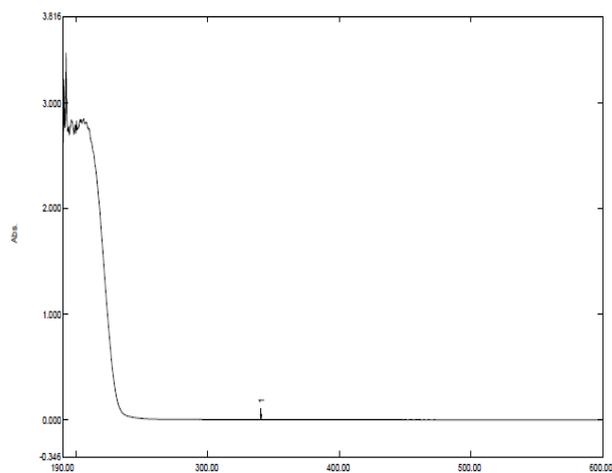


Fig.3.UV-Vis spectrum of LHSTS crystals

The optical absorption spectral analysis of the grown crystal was carried out between 200-600 nm using VARIAN CARY 5E spectrometer and is shown in the fig.3. It is observed from the spectrum that there is very low absorbance in the entire visible region and shows maximum absorption at UV region. This is one of the most desirable properties of the crystals for the fabrication of optical devices. The UV cutoff wavelength was found to be at 230 nm

3.4. Thermal analysis

The thermo gravimetric analysis of L-Histidine Sodium Thiosulphate crystals was carried out for the sample weight of 8.820 mg between 50 to 1000° C at a heating rate of 20 K min⁻¹ in nitrogen atmosphere using NETZSCH STA 409 C/CD thermal analyzer and the resultant spectrum is shown in the fig. 4. The TGA illustrates that there is no loss below 200° C illustrating the absence of water in the crystal lattice and the sharp weight loss at 180° C, without any intermediate stages, is assigned as melting point of the crystal. After that above 200° C the crystal sharply starts to decompose at 640°C. The sharpness of this peak shows the good degree of crystallinity and purity of the sample. Thus from the thermal studies, the crystal can retain its texture upto 200° C.

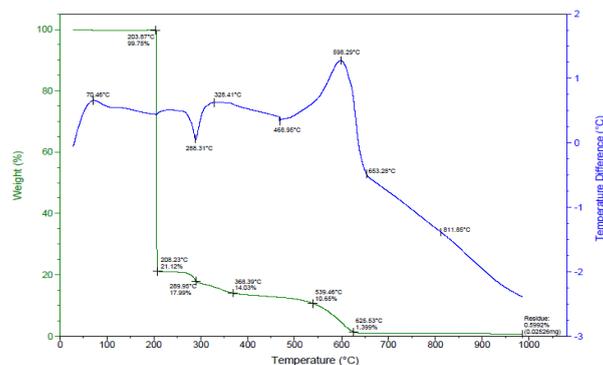


Fig.4. TG/DTA Spectrum of LHSTS crystals

3.5. Microhardness study

The microhardness studies were carried out to determine the mechanical strength of the grown LHSTS single crystal using HMT 2 T, Vicker's micro hardness tester. The indentation marks were made on the surface of LHSTS single crystal at room temperature by applying load of 25, 50 g. The Hv is found to increase with increase in the load from 25 to 50 g and crack occurs at higher loads. A graph has been plotted between Hv and applied load P. The Vicker's microhardness number Hv of the crystal was calculated using the relation $Hv = 1.8544 P/d^2$ kg/mm²; here, Hv is the Vicker's hardness number in kg/mm², P is the applied load in kg and d is the average diagonal length of the indentation in mm. From the graph the hardness value increased before 50g and decreased with increase of applied load, which may be due to the release of internal stresses generated with indentation. The grown crystal could withstand a mechanical strength (hardness) of 29.45 kg/mm².

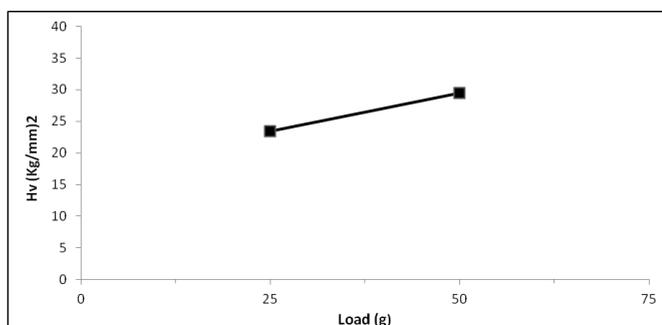


Fig. 6. Plot of load (vs.) H_v for LHSTSP crystal

3.6. NLO test

The second harmonic generation efficiency measurement was carried out on the grown crystal using the Kurtz Perry powder technique. The crystal was grounded into a homogenous powder of particles and densely packed between two transparent glass slides. The powder sample with average particle size 100-115 μ were illuminated using Q-switched Nd : YAG laser emitting a fundamental wavelength of 1064 nm with the pulse width of 8ns. The second harmonic generations were confirmed by the emission of green radiation (532nm). The output power is found to be greater than that of KDP.

4. Conclusions

Optically good quality crystals of LHSTS were grown by slow evaporation solution growth technique at room temperature. The functional groups were confirmed from FTIR analysis. The thermal stability of the materials was established by TG/DTA and it is observed that the material is stable up to 200° C. Vickers microhardness was calculated in order to understand the mechanical stability of the grown crystals. The NLO property of the crystal was examined by performing Kurtz powder test using Nd:Yag laser. Thus LHSTSP crystal can be used as an effective material for nonlinear optical applications.

References

- [1] H.O. Marcy, M.J. Rosker, L. Warren, P.H. Cunningham, C.A. Thomas, L.A. Deloach, S.P. Velsko, C.A. Enners, J.H. Liao, M.G. Kamatzidis, *Opt. Lett.* 20 (1995) 252-261.
- [2] Manoj K. Gupta, Nidhi Sinha, Binay Kumar, *Physica B: Condensed Matter*, 2011; 406: 63-7.
- [3] Maadeswaran P, Chandrasekaran J, Thirumalairajan S, *Optik - International Journal for Light and Electron Optics*, 2011; 122: 259-62.
- [4] Bhaskaran A, Raghavan CM, MohanKumar R, Jayavel R, *Current Applied Physics*, 2010; 10: 1261- 66.
- [5] Dhanaraj PV, Rajesh NP, Vinitha G, Bhagavannarayana G, *Materials Research Bulletin*, 2011; 46: 726 - 31.
- [6] Chithambaram V, Jerome Das S, Krishnan S, *Journal of Alloys and Compounds*, 2011; 506: 4543 - 46.
- [7] Lydia Caroline M, Sankar R, Indirani RM, Vasudevan S, *Materials Chemistry and Physics*, 2009; 114: 490 - 94.
- [8] Vijayan N, Rajasekaran S, Bhagavannarayana G, Ramesh Babu R, Gopalakrishnan R, Palanichamy M, Ramasamy P, *Cryst. Growth Des.* 2006; 6: 2441- 45.
- [9] Santhakumari R, Ramamurthi K, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 2011; 78: 653-59.
- [10] P.N. Prasad, D.J. Williams, Wiley-Interscience, New York, 1991.
- [11] D. Jaikumar, S. Kalainathan, G. Bhagavannarayana, *Physica B: Condensed Matter*, 405 (2010) 2394.
- [12] K.C. Bright, T.H. Freeda, *Physica B: Condensed Matter* 405 (2010) 3857.
- [13] Marcy HO, Rosker MJ, Warren LF, Cunningham PH, Thomas CA, Deloach LA, Velsko SP, Ebbers CA, Liao JH, Kanatzidis MG, *Opt. Lett.* 1995; 20: 252 - 54.
- [14] Esthaku Peter M, Ramasamy P, *J. Cryst. Growth*, 2010; 312: 1952-56.
- [15] Sabari Girisun TC, Dhanuskodi S, Mangalaraj D, Phillip J, *Current Applied Physics*, 2011; 11: 838 - 43.
- [16] K. Kirubavathi, K. Selvaraju, R. Valluvan, N. Vijayan, S. Kumararaman, *Spectrochimica Acta Part A* 69 (2008) 1283.